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FILAMENT ERUPTIONS AND THE IMPULSIVE PHASE OF SOLAR FLARES

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We examine the observed development of filament eruptions in the impulsive phase of flares for evidence of how the eruption is driven. A ~~One~~ possibility sometimes adopted as ~~a~~ working hypothesis is that the filament eruption and accompanying coronal mass ejection are consequences of ~~the~~ energy release in the flare impulsive phase; they are taken to be ejecta in the explosion resulting from the pressure pulse from ~~the~~ plasma heating in the flare. We present evidence against this view. The evidence is from four flares in which, in Hα movies ~~from~~ Big Bear Solar Observatory, a filament eruption was observed during the flare impulsive phase defined by the E $\gtrsim$ 30 keV hard X-ray emission observed with the University of California at Berkeley detector on the ISEE 3 spacecraft. In each case we find (1) ~~the well-known result~~ that ~~the~~ filament eruption began before ~~the~~ onset of the impulse phase; (2) ~~that the~~ eruptive motion is consistent with a smooth evolution through the impulsive phase, accelerating, but showing no new acceleration attributable to the

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impulsive phase; (3) ~~that~~ the brightening of the Hα flare ribbons in the impulsive phase occurring in compact areas is much smaller than the overall span of the erupting filament; and (4) ~~that~~ the observed projected speed is on the order of 100 km s^{-1} at the onset of the impulsive phase. These characteristics indicate that ~~the~~ filament eruption is not driven by ~~the~~ flare plasma pressure, but instead marks an eruption of magnetic field driven by a global MHD instability of the field configuration in the region of the flare. It appears that the filament eruption and the impulsive energy release are coordinated and driven by a common cause, the instability of the whole field configuration. A new mode of energy release, that of the impulsive phase, may be initiated when the eruptive motion surpasses some speed limit of order 100 km s^{-1}.

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1. INTRODUCTION

A flare is an explosion in the solar atmosphere, a sudden burst of particle acceleration, plasma heating, and bulk mass motion. Because flares occur only in magnetic regions and strongly favor sites where the magnetic field is greatly deformed from its potential, minimum-energy configuration, it is likely that flares draw their energy from the free energy stored in the nonpotential magnetic field (Svestka 1976; Gary et al. 1987; Machado et al. 1987; Moore 1987).

The magnetic field in which a flare occurs is basically bipolar. The configuration consists of a single overall bipole or of two or more distinct bipoles impacted against each other, each bipole having its own internal polarity inversion line (the dividing line between the two opposite polarity domains of the bipole) (Moore et al. 1980; Machado et al. 1987). Many flares have a dominant bipole which is evidently nonpotential and in which most of the energy release occurs (Machado et al. 1987). In this bipole, the flare typically starts out closely straddling the inversion line and then spreads away (Svestka 1976; Moore et al. 1984).

A clear and common sign of nonpotential stress in a bipole is strong magnetic shear across the polarity inversion line; instead of connecting directly across the inversion line as it would if the field were potential, the field near the inversion line runs almost parallel to it (Hagyard, Moore, and Emslie 1984; Moore and Rabin 1985). Such sheared magnetic field is often marked by a filament of dark chromospheric material tracing the inversion line (e.g., see Figure 1). When a flare occurs in such a bipole, the inversion line and the sheared field traced by the filament are

embedded in the flare. In the onset and impulsive phases of such flares, chromospheric movies often show impressive eruptive action of the filament and hence of the field that carries it (Kiepenheuer 1964; Zirin 1970; Martin and Ramsey 1972; Moore et al. 1984).

In some flares the filament eruption is arrested and confined within the bipole (Svestka 1986; Machado et al. 1987; Moore 1987). In other cases the eruption opens the bipole, and the field in and around the filament is ejected out into the corona and escapes into the solar wind; such a filament ejection viewed in a chromospheric movie is called a flare spray (Tandberg-Hanssen, Martin, and Hansen 1980). Viewed in coronagraph images, the filament material and the magnetic field traced by it are often seen to ride in the core of a coronal mass ejection (CME) (Webb and Hundhausen 1987). Because a filament ejection is an integral part of many CMEs, study of the initiation of filament eruptions may yield clues to how CMEs are launched.

One working hypothesis for numerical modeling of CMEs from flares has been that the mass ejection is basically the consequence of a pressure pulse generated by the sudden intense heating marked by the impulsive hard X-ray burst and steeply rising soft X-ray emission in the flare impulsive phase (Dryer 1982). Estimates of the total energy released, based on thick-target interpretation of hard X-ray bursts from large flares, give enough energy (> 10^{32} erg) for even the largest CMEs (Lin and Hudson 1976). On the other hand, it is known that in most large flares with filament eruptions, the filament begins to erupt several minutes or more before the onset of the impulsive phase of the flare (Martin and Ramsey 1972). It is also fairly certain that many CMEs begin before the impulsive phase onset of the flares with which they are associated (Harrison 1986). The early

start of filament eruptions and CMEs casts doubt on the identification of the pressure pulse as the driver for CMEs; this raises the question of how the impulsive energy release is involved in the launching of filament eruptions and CMEs.

To investigate this question we have closely examined the filament motion through the onset of the impulsive phase in four flares for which the impulsive phase onset was well defined by an observed hard X-ray burst and in which the filament motion could be well followed in an Hα movie. We find that in each of these flares the filament began to erupt minutes before the impulsive phase onset, and the motion evolved smoothly through impulsive phase onset, showing no basic change in character at that time. This indicates that the impulsive flare energy release is not the driver of the filament eruption, and hence is not the cause of filament ejections and CMEs.

II. DATA ANALYSIS

We began with a listing of all Hα flares observed at Big Bear Solar Observatory (BBSO) and reported as 1B or larger (Solar-Geophysical Data 1979-1983) after the launch of the ISEE-3 spacecraft in August 1978. From over 200 candidate flares we selected for detailed examination four flares meeting the following criteria:

(1) The BBSO Hα photographic coverage was complete during the preflare and flare rise phases, and the motion of an eruptive filament in the flare region could be followed well into the impulsive phase before the filament disappeared from the observing bandpass. Both on-band and blue wing ($\Delta\lambda = -0.6$ Å) off-band images were used.

(2) A well defined hard X-ray burst was observed by the UC Berkeley scintillator experiment on the ISEE-3 spacecraft (Anderson et al. 1978).

(3) The flare occurred sufficiently far from the limb that the position of the impulsive phase Hα brightenings relative to the erupting filament could be determined.

Many candidate flares lacked overlapping Hα and hard X-ray coverage. In other cases the Hα filament was faint or faded quickly from the Hα bandpass when the flare began. The four selected events, listed in Table 1, were selected from a viewing of the Hα movies. For each of the four events we selected images at appropriate times and made prints with a scale of 8700 km (12 arc sec) = 1 cm. The relative positions of the outermost parts of the erupting filaments were measured on each print. In addition, the positions of the impulsive phase Hα brightenings were also traced out. For each event, discussed in detail below, we show in one figure images of the moving filament and a diagram of the positions of the

impulsive phase Hα brightenings relative to the filament. A second figure shows the time series of the relative filament displacements (projected in the plane of the sky) and hard X-ray fluxes. In these figures the solid vertical line shows the approximate time of onset of the hard X-ray burst and the dashed vertical lines bracket the onset of the Hα flash phase estimated from the Hα movies.

a) The Flare of 1979 April 26.

The flare occurred in McMath plage region 15967, a large region with a bipolar magnetic structure. In Figure 1 we show the Hα flare emission regions and the increase in the emission areas from early in the flare at 2001:08 UT to just after the peak of the hard X-ray burst at 2002:51 UT. The strongest impulsive brightenings were along the magnetic inversion line centered approximately under the filament. Some weaker enhancement of Hα emission was also seen near the filament footpoints. Most of the Hα brightenings near the northern footpoint occurred before the flare impulsive phase.

In Figure 2 the filament displacement measured from the Hα images shows that the large filament structure was already moving eastward with a projected speed of ~ 5 km$\cdot$s^{-1} at 1956 UT. The hard X-ray burst began just before 2002 UT and peaked at 2002:36 UT, as shown in Figure 2. Before 2003 UT, the bandpass of the Hα filtergrams was centered on the line; after 2003 UT, the images were made in the blue wing of the line. We found good agreement between the on-band and off-band displacements near 2003 UT, showing that the same filament feature was being tracked throughout the event.

b) <u>The Flare of 1980 May 28.</u>

The flare occurred in plage region 16863, a large bipolar region in its first solar rotation. The observations used here were obtained in the blue wing of Hα (Figure 3). The impulsive phase of this event consisted of at least two separate bursts, the first peaking at 2338:16 UT, the second at about 2338:40 UT (Figure 4). The most prominent Hα brightening associated with the first peak was centered under the arch of the erupting filament at point A (Figure 3). It was very bright in the 2338:20 UT image, but almost invisible in the images 10 sec before and 10 sec after that time. Subsequent brightenings appeared as bipolar features near the northern and southern footpoints of the filament. In addition, another large region of Hα emission appeared well to the north of the filament region.

c) <u>The Flare of 1980 June 25.</u>

This flare occurred in plage region 16923, a new complex region joined to another region on its second disk passage. Observations were obtained in both the center of the Hα line and its blue wing. The latter show the erupting filament burst (Figure 5). The Hα brightenings during the onset of the impulsive phase show double ribbon features, particularly near the western end of the filament where the eruption proceeded most rapidly. The large displacement of the filament from the ribbon suggests that the filament overlay magnetic arches connecting the opposite polarities of the double ribbon. Another bright emission region lay well to the west of the filament. An isolated emission patch also appears in the spots to the east of the filament and may lie at the eastern footpoint of the filament. That

end of the filament was the more slowly moving part of the eruption. The hard X-ray profiles and filament displacements are shown in Figure 6.

d) The Flare of 1981 July 27.

The flare occurred in plage region 17760, a large bipolar region on its second disk passage. Zirin (1983) has studied the magnetic development of this region during the July 26-27 period of flare activity. His Figures 7 and 8 show the July 27 flare in Hα and D_3 emission respectively. Our Figure 7 shows that the impulsive phase Hα brightenings were widespread throughout the region. The D_3 regions mark the positions of the peaks of the hot thermal plasma presumed due to the most intense energetic electron precipitation. We show three such regions in this event. One is a large region lying partially in the sunspot to the east of the filament. A second is centered directly under the filament and appears to be a small bipolar structure on the magnetic inversion line. The third also appears as a bipolar feature near the northern footpoint of the filament. Kattenberg (1984) has discussed the 2 cm maps of this event. He shows two small 2 cm structures at ~ 1724 UT, each of dimensions 2 arc sec by 10 arc sec and separated by 10 arc sec. One feature corresponds to our second region centered under the filament (his images are rotated 180° from ours and Zirin's). Kattenberg reports them to be small features oriented perpendicularly to the magnetic inversion line and interprets them as small low-lying loops possibly newly formed by reconnection. The filament displacements and hard X-ray profiles for this event are shown in Figure 8.

III. ANALYSIS OF THE FILAMENT MOTION

In all four cases the filament displacement is seen to undergo a smooth

evolution through the onset of the impulsive phase (Figures 2,4,6, and 8). The displacement profiles at those times show little change of slope in the 26 April and 25 June events, but the slopes steepen substantially in the 28 May and 27 July events. This suggests that the filaments of the latter two events may differ qualitatively in their motion from the former two events. We have fitted each of the profiles to an analytical trajectory in which we arbitrarily assume an acceleration a, which varies monotonically in time according to

$$a = ct^{b}, \tag{1}$$

where t is time and c and b are constants. The resulting displacement is

$$\Delta x = v_0 t + c(b + 1)^{-1}(b + 2)^{-1}t^{(b + 2)}, \tag{2}$$

where v_0 is the speed observed at the beginning ($t = 0$) of the observations. By estimating the initial slope of the points and requiring the curve to be a good fit near the middle and end of the observing interval, we evaluate the parameters b and c. The computed trajectories are shown as the smooth curve fits to the observed displacements at the bottoms of Figures 2, 4, 6, and 8. The power law exponent, b, of the acceleration equation (1) is definitely positive in all but the 25 June event, for which it was close to 0. All the filament displacements are well fitted by the curves through the onsets of the hard X-ray bursts and flash phases and show no evidence of any additional acceleration at those times. Hence, it appears that all four filament eruptions belong to a single family well described by smoothly varying acceleration.

The calculated filament displacements, speeds, and accelerations at the onsets of both the hard X-ray burst and the Hα flash phase are shown in Table 2. Uncertainties are stated to reflect the range of possible

times for the Hα flash phase. We note that the speeds at either the hard X-ray burst onset or the flash phase were all in the narrow range 30-180 $km \cdot s^{-1}$. This suggests that the impulsive phase energy release may not be initiated until a threshold speed of the eruptive filament has been achieved. The accelerations show a much broader range of values and, in view of the subjective nature of the fits to equation (2), must be considered to be less certain.

IV. DISCUSSION AND CONCLUSIONS

We have examined filament motions during the onset of the flare impulsive phase. The impulsive phase onset was established from the profiles of ~ 30 keV X-ray fluxes and the rapid flare brightenings characteristic of the Hα flash phase. The general temporal and spatial association of these brightenings with impulsive hard X-ray bursts has been clearly established in previous studies (e.g., Diujveman, Hoyng, and Machado 1982; Diujveman and Hoyng 1983). We find the following:

(1) The filament motion begins several minutes before the impulsive or flash phase of the flare.

(2) No change occurs in the character of the motion of the filament during the onset of the impulsive phase of the flare.

(3) The most common Hα brightenings associated with the impulsive phase lie near the magnetic inversion line roughly centered under the erupting filament.

(4) Filament speeds at the onset of the impulsive or flash phase lay in the range 30-180 $km \cdot s^{-1}$. Accelerations were in the range 0.2-9 $km \cdot s^{-2}$.

These results were derived from observations of only four events selected from a much larger sample of candidate events. They differed from

the other events only because of their comprehensive data coverage and clear delineation of the filament position and Hα brightenings. We have no reason to think that they are uncharacteristic of filament eruptions in general; hence, the conclusions (1) to (4) should be general for most or all such events.

Our first observational result is consistent with results obtained in previous studies. For example, the motions of the filaments we found prior to the impulsive phases are manifestations of the early stages of filament activity found by Martin and Ramsey (1972) in their statistical study of 297 large flares. The early low speeds correspond to their phases of filament darkening, expansion, and breakup. This preflare activation was described earlier by Bruzek (1969) as a destabilization showing that the magnetic field had become unstable. As he put it, "Its (the activation of the filament) early start indicates that the magnetic field starts to change long before the onset of the optical flare. The final rise or eruption of the filament may then be considered as evidence of a catastrophic change of the magnetic field which simultaneously destroys the filament and generates the flare."

The important implication of the observational results (2) and (3) is that the rapid energy release in the impulsive phase does not cause, either directly or indirectly, the filament eruption. We have seen that the filament is already in motion well before the onset of the impulsive phase and that it continues to accelerate smoothly through the onset of the impulsive phase. No qualitative change of character of the motion occurs at that time. The Hα brightenings that occurred in the impulsive phase usually lay close to the magnetic inversion line under the erupting filament.

A similar result for impulsive phase brightenings was found by Feldman _et al._ (1983) using He D_3 images of bright flares. The close proximity of the brightenings to the inversion line suggests that the impulsive energy release is confined to structures, probably magnetic bipoles, with size scales an order of magnitude smaller than those of the overlying filaments. If this is the case, it would not seem plausible that a pressure increase in the impulsive phase structures could result in a driving force adequate to propel the much larger overlying magnetic structure containing the filament. We conclude that the impulsive energy release is not a requirement for the eruption of the filament or of a CME in which the filament is an integral component (Webb and Hundhausen 1987). Rather, from our observations, it appears that the magnetic eruption traced by the erupting filament, as well as the impulsive energy release, are both driven by the MHD instability, or loss of equilibrium, of the overall magnetic field configuration in which the filament and flare are embedded.

Since the flare impulsive phase is not required for the occurrence of a filament eruption or a CME, there appears little reason to distinguish on physical grounds flare-associated CMEs from those associated with the eruptions of quiescent filaments. The more likely case is that all CMEs lie on a broad spectrum ranging from the quiescent filament eruptions in weak magnetic field regions to the flare filament eruptions from active regions with strong fields (Anzer and Pneuman 1982; Cane, Kahler, and Sheeley 1986; Moore 1987). Several additional observational results support this view. First, as pointed out by Bruzek (1969), many activated filaments remain stable and do not erupt, even when a flare occurs adjacent to or below the filament. This suggests that in many cases the impulsive

phase energy may not be adequate to propel the filament eruption. Second is the observation of large double-ribbon flares with no observed impulsive hard X-ray emission (Dwivedi _et al._ 1984) and the discovery of energetic proton flares with only small impulsive phases (Cliver, Kahler, and McIntosh 1983). A notable example of an energetic eruption occurring outside an active region was the event of 1981 December 5 in which a large filament eruption unaccompanied by any impulsive phase hard X-ray or microwave burst resulted in a CME, interplanetary shock wave, and solar energetic particle event (Kahler _et al._ 1984). Tandberg-Hanssen, Martin, and Hansen (1980) have shown that the trajectories of flare sprays and filament eruptions form a broad continuum rather than showing two classes as believed earlier (Valnicek, 1964). Finally, Cane, Kahler, and Sheeley (1986) found that CMEs associated with the eruption of quiescent filaments do not necessarily lie at the low end of an energy spectrum of eruptive events. Six quiescent filament eruptions they considered gave rise to interplanetary shocks and energetic particle events, phenomena usually presumed to be associated only with flare events. These several observational results indicate no requirement for an impulsive phase in an eruptive event.

Having shown that the flare filament eruption occurs essentially independently of the impulsive phase, one can ask what the relationship, if any, is between the two phenomena. We found (Table 2) that the onset of the impulsive phase seems to occur only during a limited range of filament speeds (30–180 $km \cdot s^{-1}$) and accelerations (0.2–9 $km \cdot s^{-2}$). These speeds are about one tenth the Alfven speed, the most likely physically relevant speed. We speculate that these speeds are somehow critical for the

occurrence of the impulsive phase energy release. In agreement with this, we note that the speeds of eruptive quiescent filaments, events with no observed impulsive phases, are lower than 100 $km \cdot s^{-1}$ until after they leave the vicinity of the filament region ($h < 2 \times 10^5$ km) (Schmahl and Hildner 1977, MacQueen and Fisher 1983). In addition, flare sprays, which originate from active region filaments and are probably always accompanied by flare impulsive phases, reach speeds of > 500 $km \cdot s^{-1}$ within a few minutes of the start of the events (Tandberg-Hanssen, Martin, and Hansen 1980). We suggest that all eruptive events are due to the same physical cause and that those events characterized by a rapid (< 5 min) acceleration to a speed of > 100 $km \cdot s^{-1}$ will be accompanied by an impulsive phase. The impulsive phase, however, is only a secondary effect and plays no direct role in the eruptive event. In this sense the impulsive phase may perhaps be regarded as an effect of the eruptive event, a complete reversal of the roles previously attributed to these phenomena.

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TABLE 1

Characteristics of the Four Flares with Filament Eruptions

Date	Hα Onset (UT) and Importance		Position	Region	GOES 1-8 Å Peak	Maximum 26-43 keV Flux (cts/sec)	8800 MHz Max Flux (s.f.u.)
1979 April 26	2001	1B	N11 E31	15967	C7	5.6×10^2	60
1980 May 28	1550	1B	S28 W29	16863	M6	1.4×10^3	270
1980 June 25	2338	1B	S16 W36	16923	M4	2.5×10^2	400
1981 July 27	1723	1B	S13 E10	17760	X1	$\sim 6 \times 10^3$	1800

TABLE 2

Characteristics of Filament Eruption at Impulsive Phase Onset

Date	IHXB[a] Onset (UT)	HFP[b] Onset (UT)	Displacement[c] (10^3 km)	Speed ($km \cdot s^{-1}$)	Acceleration ($km \cdot s^{-2}$)
1979 April 26	2001:46		17	88	0.31
		2001:55 ± 35	18 ± 3	91 ± 12	0.32 ± .06
1980 May 28	2338:03		5.9	75	1.30
		2338:10 ± 10	6.5 ± 1.0	85 ± 15	1.50 ± 0.25
1980 June 25	1549:56		7.8	91	0.25
		1550:25 ± 15	10.8 ± 1.8	98 ± 10	0.22 ± 0.01
1981 July 27	1723:16		2.4	28	0.26
		1723:55 ± 15	$4.2^{+2.0}_{-1.0}$	85^{+92}_{-40}	$3.95^{+4.8}_{-2.3}$

a. IHXB = Impulsive Hard X-ray Burst (26-43 keV).

b. HFP = Hα Flash Phase. The uncertainties given in the other columns are those resulting from the uncertainty in HFP onset.

c. Measured in the plane of the sky.

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FIGURE CAPTIONS

Figure 1. Top: The Hα flare of 26 April 1979 before (upper left, on band) and during (upper right, blue wing) the impulsive phase. Bottom left: Diagram of the impulsive phase brightening of the event. Shaded regions trace the filament. The heavy lines show the regions of new Hα brightenings present during the impulsive phase image at 2002:51 but not observed in the earlier image at 2001:08 UT. Thin lines indicate the extent of the Hα flare regions in the earlier image. The dashed line shows the estimated magnetic inversion line. The arrow shows the outer extreme of the erupting filament used in measuring the displacement shown in Figure 2.

Figure 2. Top: Counting rates of the 26-78 keV X-rays during the 26 April 1979 flare. Bottom: The relative filament displacements are shown by circles; filled circles are from on-band images, and open circles are from off-band images. Vertical arrows show the filament displacements at the times of the Hα images of the top of Figure 1. The solid vertical line marks the X-ray onset of the impulsive phase. The dashed lines show the earliest and latest possible onset of the Hα flash phase as determined from the movie.

Figure 3. Top: The Hα flare of 28 May 1980. Details are similar to those described in Figure 1 except that both images are in the blue wing of Hα. Point A in the lower diagram was the brightest region during the first peak in the impulsive phase.

Figure 4. X-ray counting rates and filament displacements for the 28 May 1980 flare. Details are similar to those of Figure 2.

Figure 5. The Hα flare of 25 June 1980. Details are similar to those

described in Figure 1 except that both images are in the Hα blue wing.

Figure 6. The X-ray counting rates and filament displacements for the flare of 25 June 1980. Details are similar to those in Figure 2.

Figure 7. The Hα flare of 27 July 1981. Details are similar to those described in Figure 1 except that both images are in the Hα blue wing and we show as dotted areas the regions of the D_3 emission at 1724:35 UT (Zirin 1983).

Figure 8. The X-ray counting rates and filament displacements for the flare of 27 July 1981. Details are similar to those in Figure 2.

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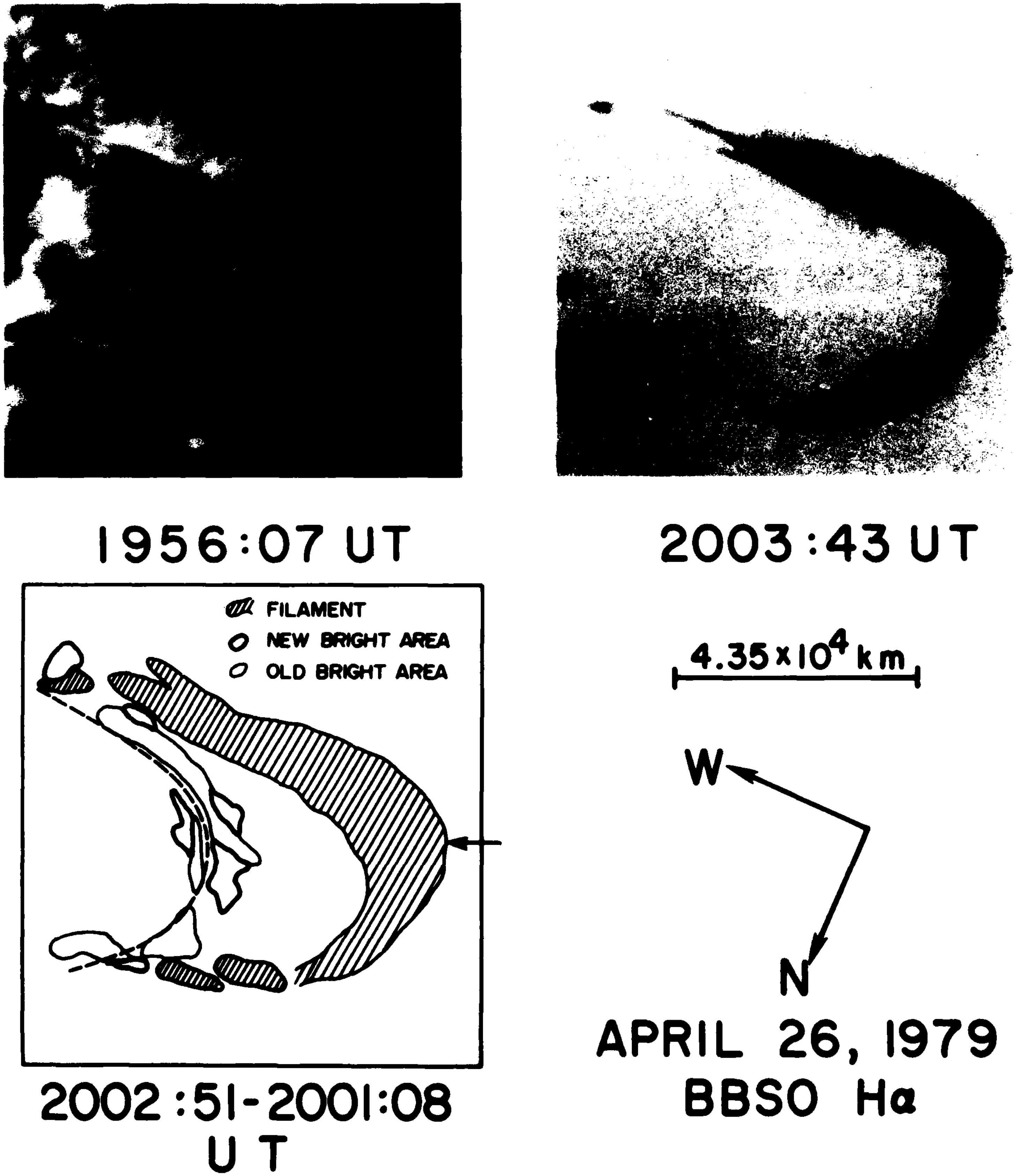

1956:07 UT
2003:43 UT
FILAMENT
NEW BRIGHT AREA
OLD BRIGHT AREA
2002:51-2001:08
U T
4.35 x 10⁴ km
W
N
APRIL 26, 1979
BBSO Hα

Figure 1

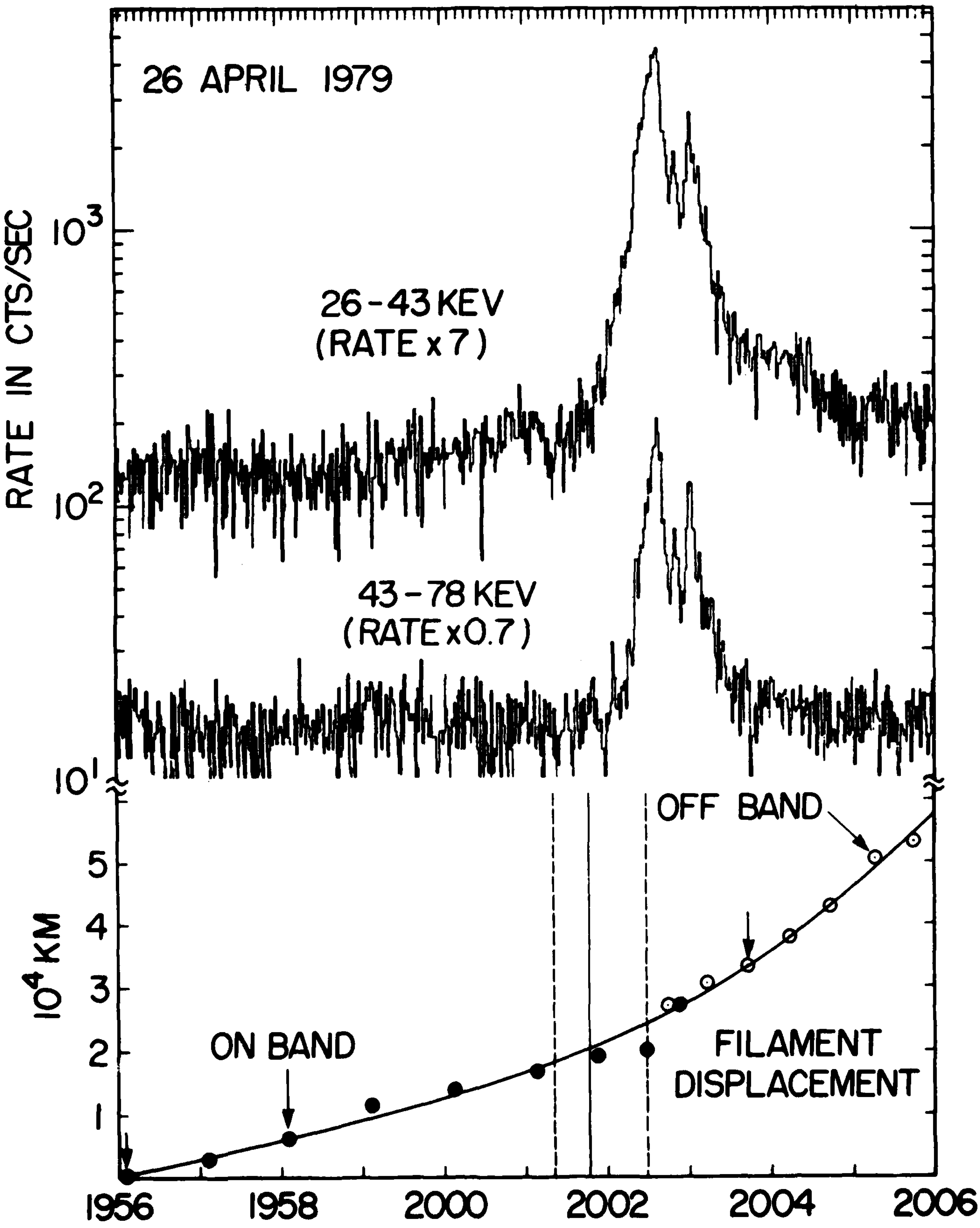

26 APRIL 1979
RATE IN CTS/SEC
10^3
10^2
10^1
26-43 KEV
(RATE x 7)
43-78 KEV
(RATE x 0.7)
OFF BAND
ON BAND
FILAMENT
DISPLACEMENT
10^4 KM
5
4
3
2
1
1956
1958
2000
2002
2004
2006
UT

Figure 2

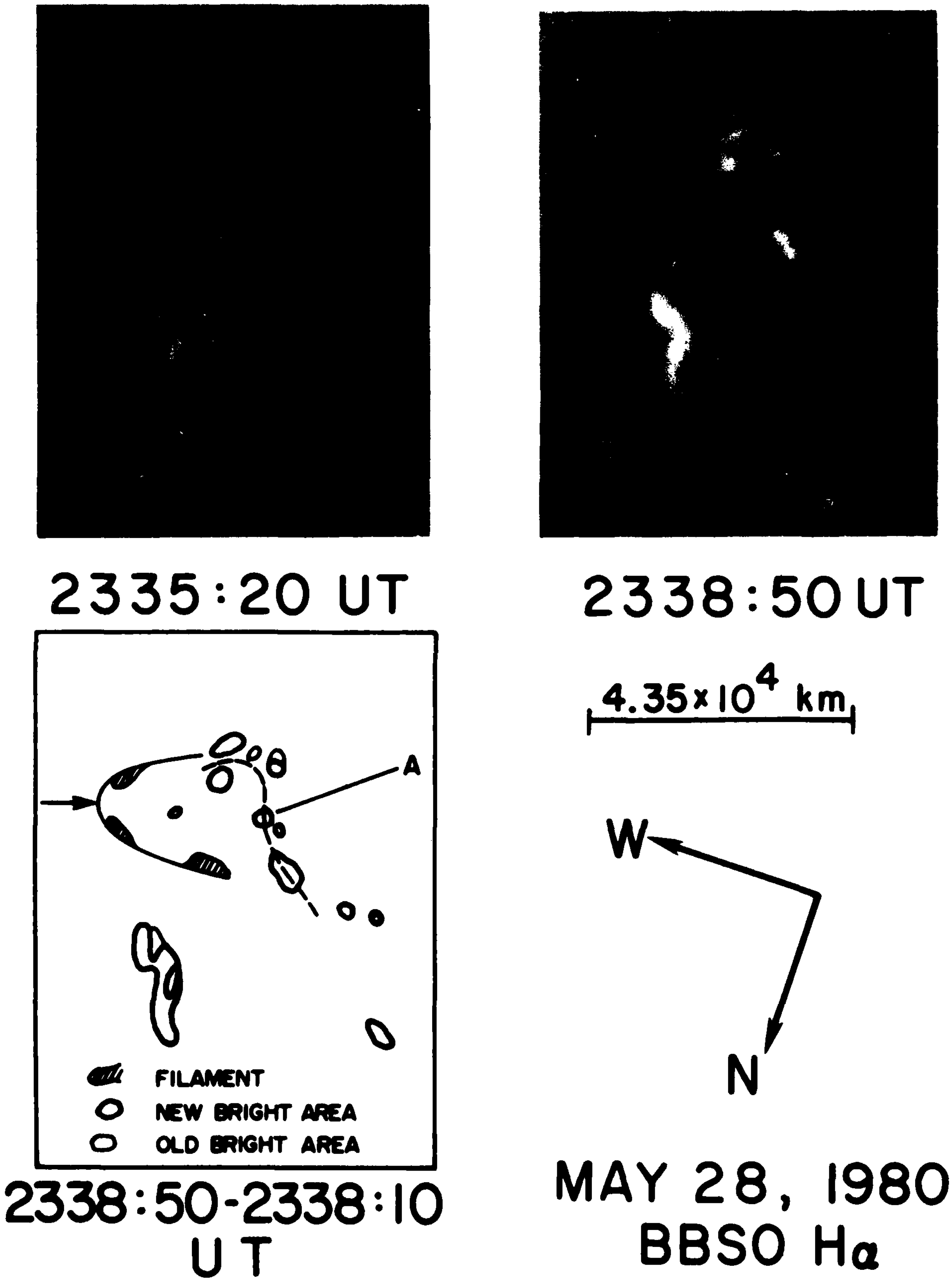

2335:20 UT
2338:50 UT
FILAMENT
NEW BRIGHT AREA
OLD BRIGHT AREA
A
2338:50-2338:10
U T
4.35x10^4 km
W
N
MAY 28, 1980
BBSO Hα

Figure 3

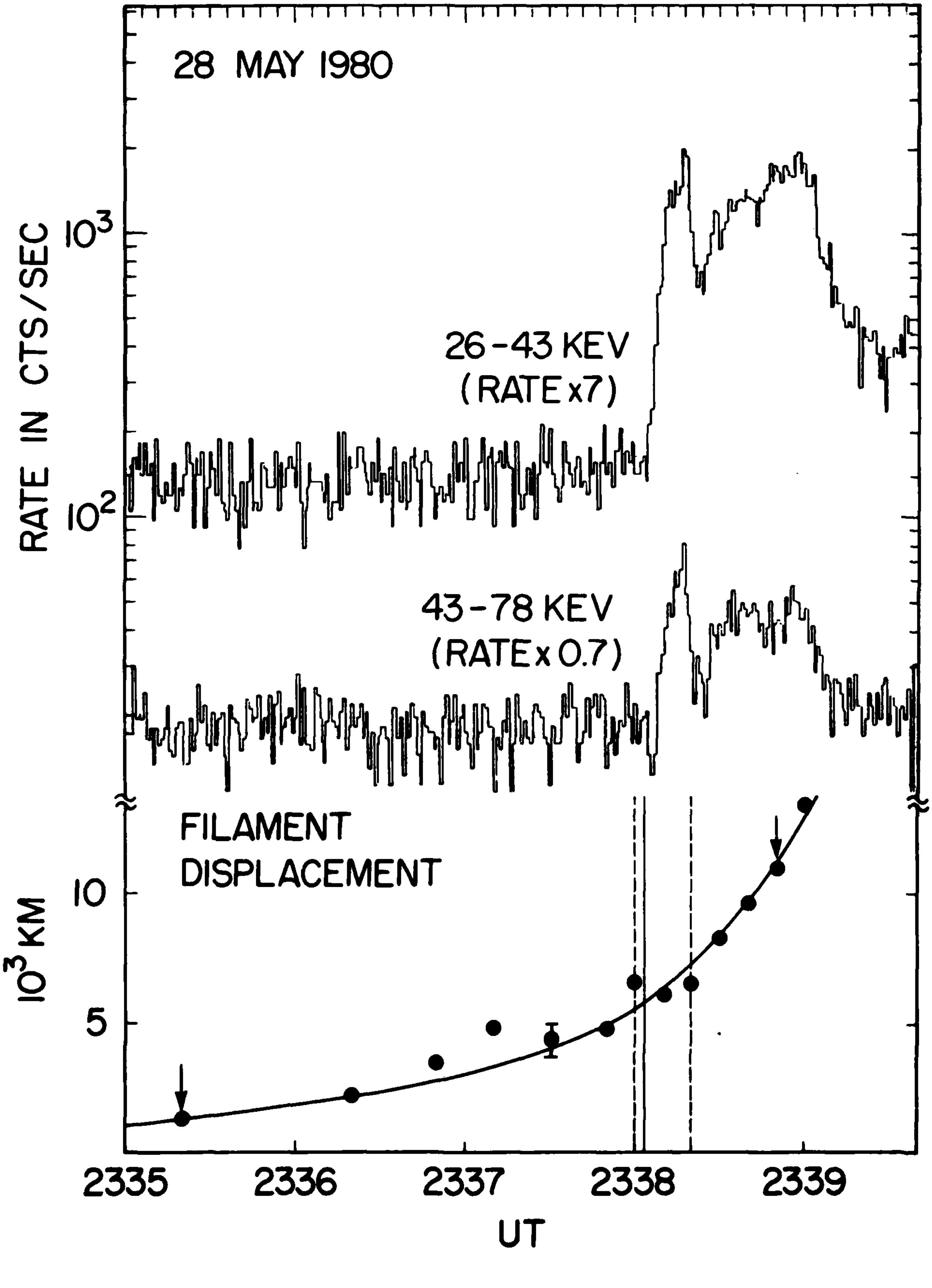

28 MAY 1980
RATE IN CTS/SEC
10^3
10^2
26-43 KEV
(RATE x7)
43-78 KEV
(RATE x 0.7)
FILAMENT
DISPLACEMENT
10^3 KM
10
5
2335
2336
2337
2338
2339
UT

Figure 4

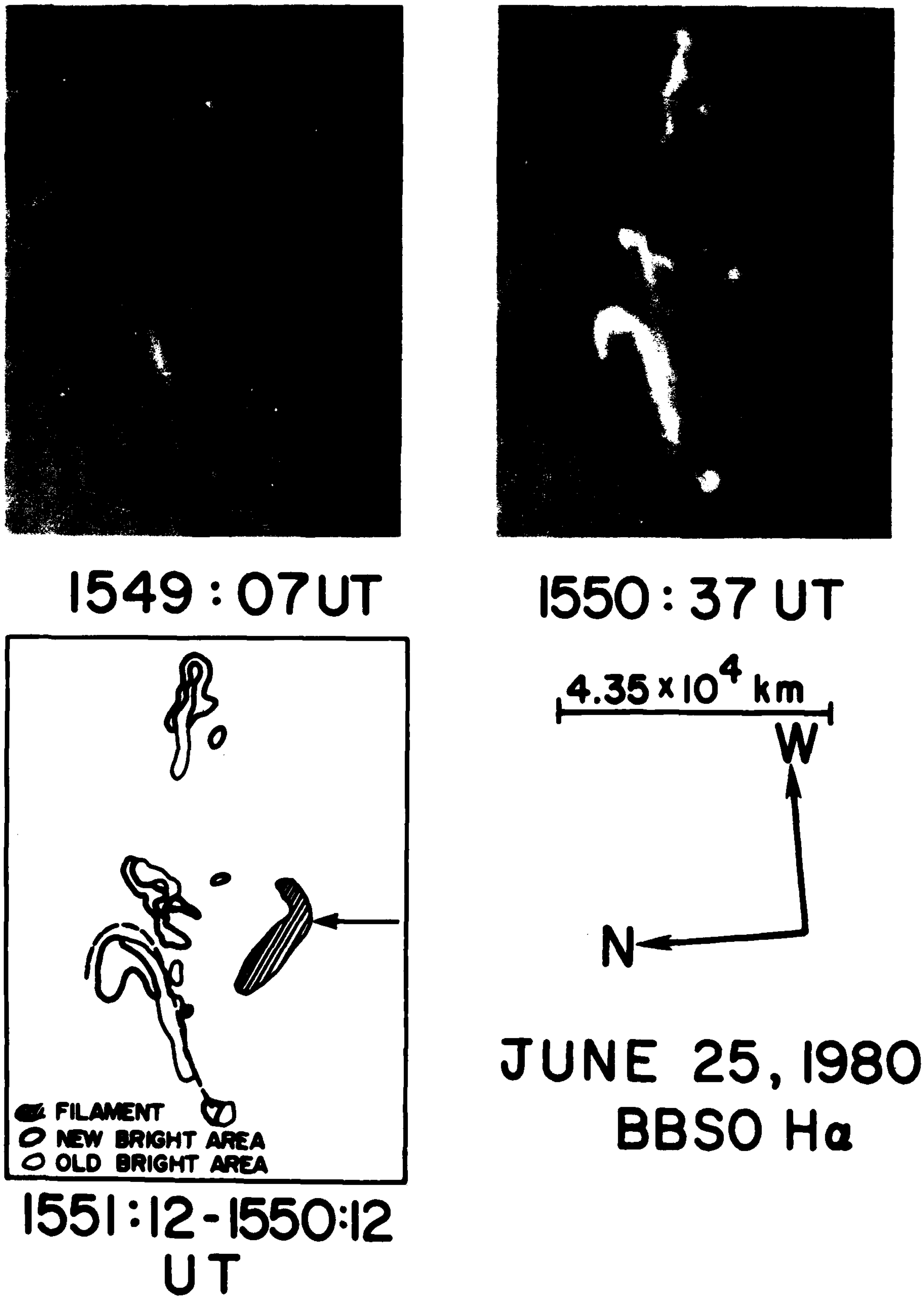
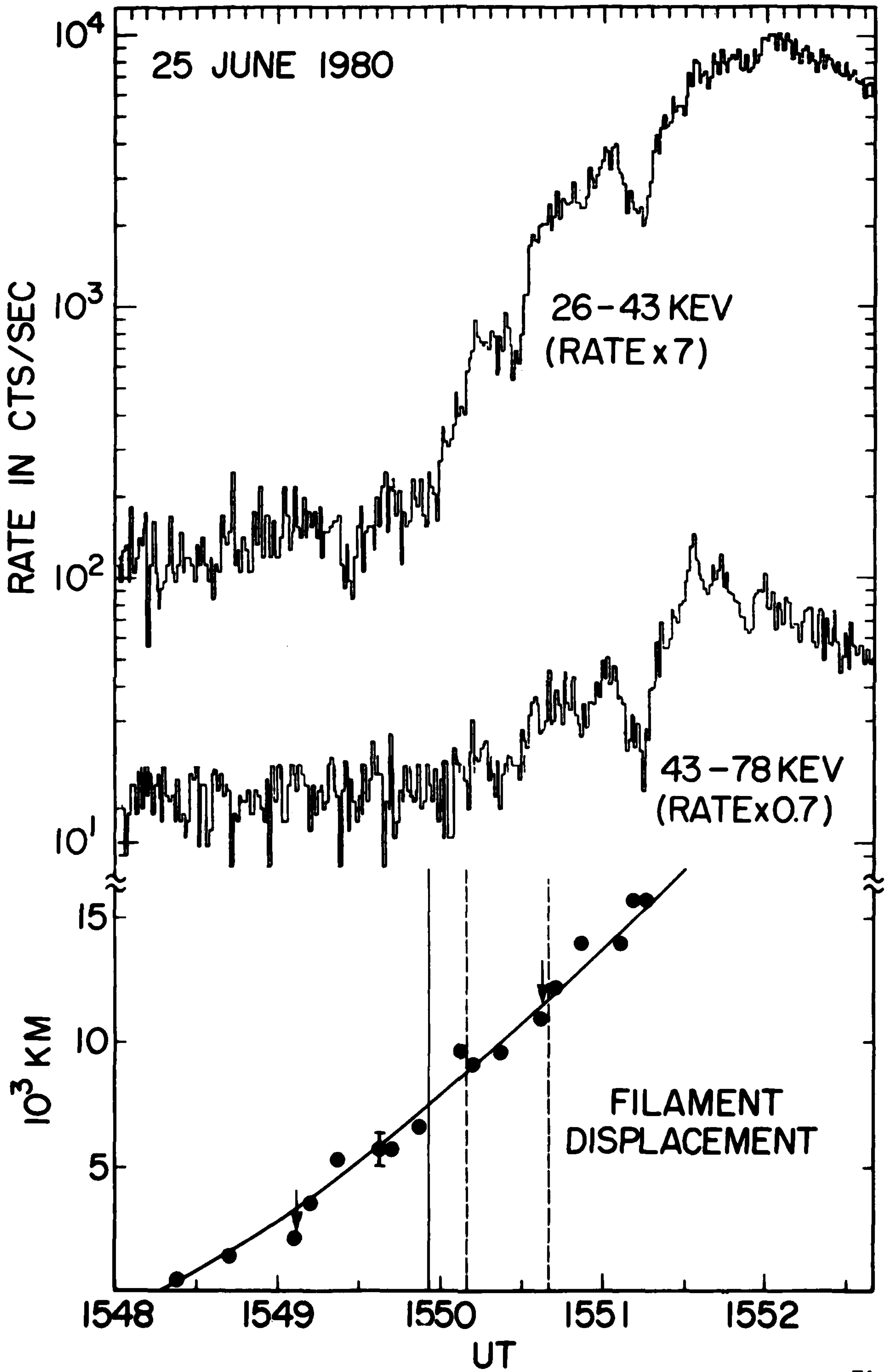
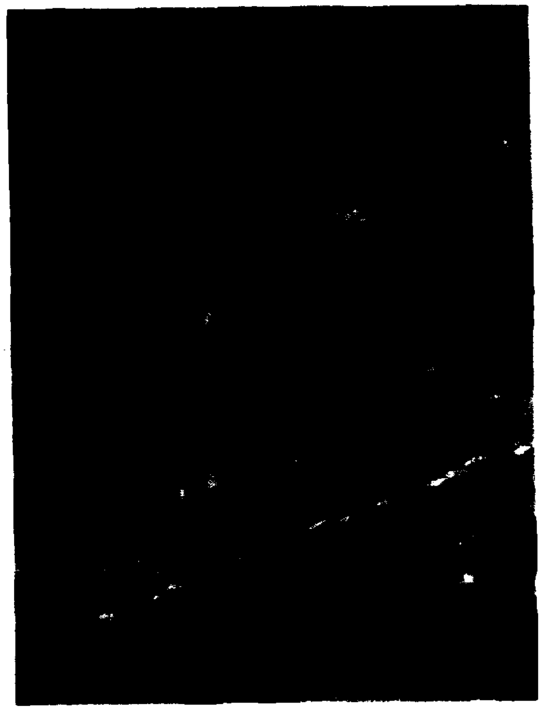

1549 : 07 UT
1550 : 37 UT
4.35 x 10^4 km
W
N
FILAMENT
NEW BRIGHT AREA
OLD BRIGHT AREA
1551:12-1550:12 UT
JUNE 25, 1980
BBSO Hα

Figure 5



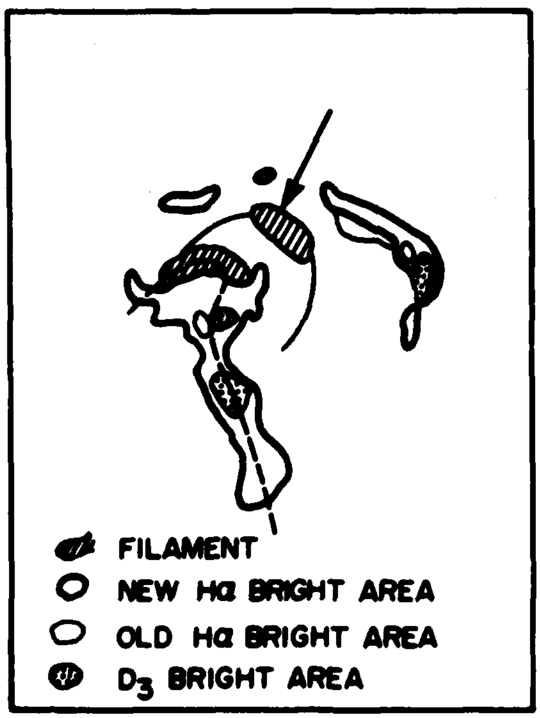
25 JUNE 1980
RATE IN CTS/SEC
10^4
10^3
10^2
10^1
26-43 KEV
(RATE x 7)
43-78 KEV
(RATE x 0.7)
10^3 KM
15
10
5
FILAMENT
DISPLACEMENT
1548
1549
1550
1551
1552
UT

Figure 6



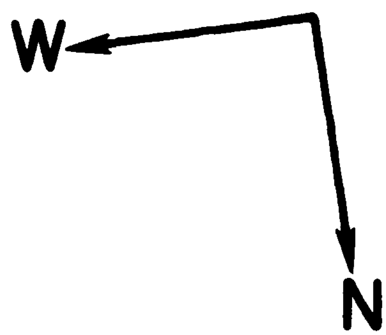
1722:57 UT

1724:27 UT



1724:27-1723:12 UT

4.35×10^4 km



JULY 27, 1981
BBSO Hα

Figure 7

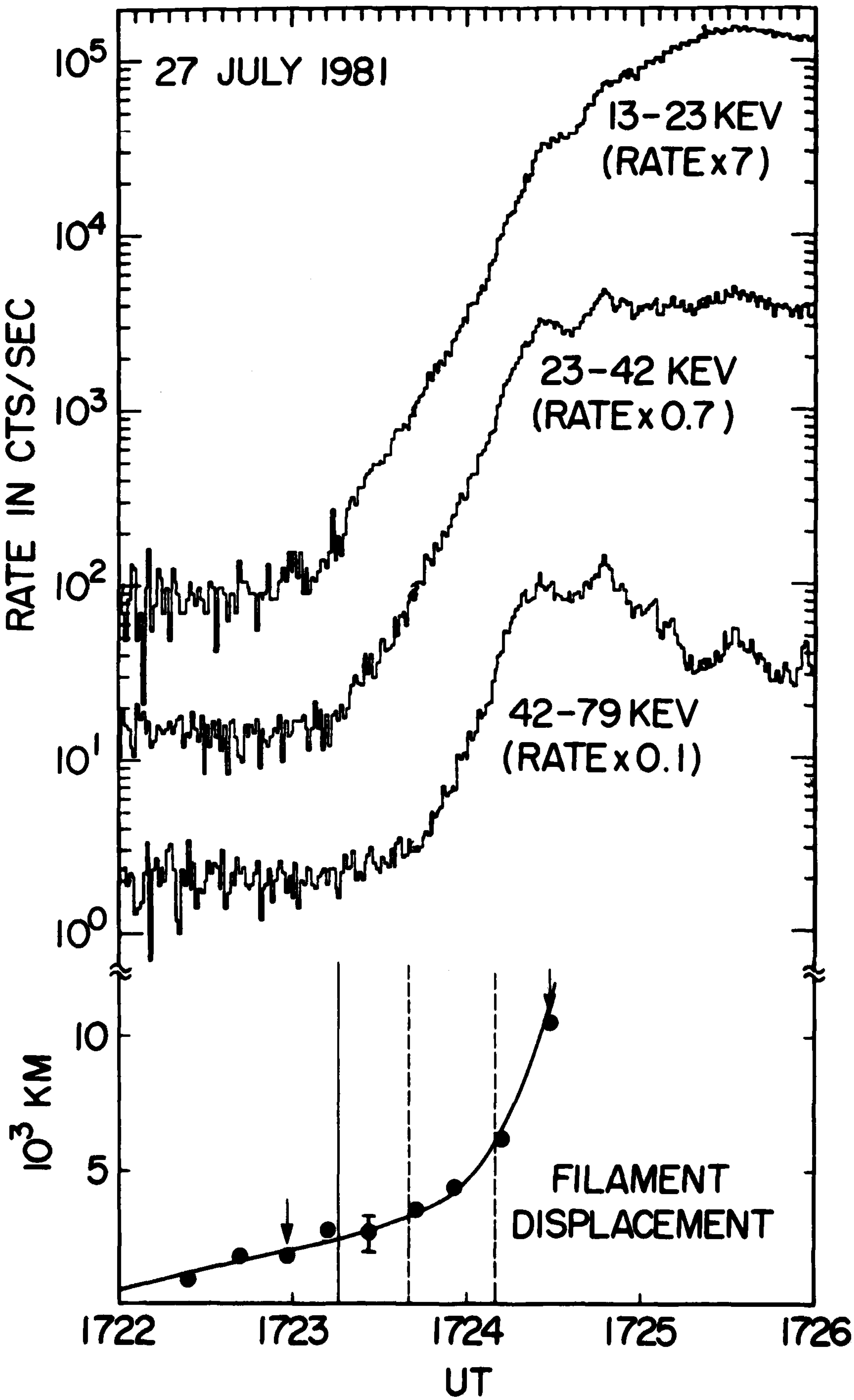

27 JULY 1981
13-23 KEV
(RATE x 7)
23-42 KEV
(RATE x 0.7)
42-79 KEV
(RATE x 0.1)
RATE IN CTS/SEC
10^5
10^4
10^3
10^2
10^1
10^0
10^3 KM
10
5
FILAMENT
DISPLACEMENT
1722
1723
1724
1725
1726
UT

Figure 8